Poroelastic Models of Stress Diffusion and Fault Re-Activation in Underground Injection

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Abstract

Stress and failure in the earth have long been observed to couple to hydrogeology. Poroelastic models, introduced by soil scientists, can account for strong two-way coupling between porous crustal rock formations and their pore fluids. Current efforts to provide new energy resources (water injection in EGS, enhanced oil recovery) and to reduce pollution (CO2 sequestration, deepwell disposal) have sparked interest in more accurately modeling these interactions. Here we focus on how fluid injection can re-activate pre-existing fractures, a scenario commonly examined by regulatory agencies. The onset of seismicity due to fluid injection is frequently expressed in terms of a critical injection pressure, Pc. Traditional methods for estimating Pc are semi-empirical and often overly conservative; moreover, they frequently have failed to match historical data. Nowadays, however, poroelastic models enable more accurate estimates of how stresses due to fluid injection propagate into and affect the surrounding rock mass. We have used COMSOL Multiphysics to calculate the pressure history in typical deepwell injection scenarios. We show that the poroelastic response of the rock mass leads, in many scenarios, to a higher critical injection pressure Pc, as compared to the traditional methods. Our proposed model-assisted method provides the benefit of a more accurate criterion for predicting the onset of failure. This method thus helps maximize injection productivity while still assuring that operations are conducted in a manner protective of human health and the environment.